

FIREFIGHTER & OCCUPANT SAFETY CONSIDERATIONS WITH “MODERN” LIGHTWEIGHT CONSTRUCTION.

Minnesota Governor’s Council on Fire Prevention and Control
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INTRODUCTION

The Governors Council on Fire Prevention and control dates back to the 1969 Legislative Session and operates today under Executive Order No. 03-04 signed by Governor Pawlenty on April 4, 2003. As an ongoing commitment of the Council, this White Paper was developed to address the issues of firefighter and occupant safety when fires occur in residential and commercial construction buildings involving lightweight and/or performance designed building materials.

BACKGROUND

Fires in today’s “modern” residential buildings pose greater risks than their (traditional solid joist) “legacy” predecessors. These structures are subject to rapid fire spread through areas of unprotected wood construction, the collapse of unprotected dimensional lumber, and the collapse of lightweight engineered wood components.

Underwriters Laboratories (UL) and its partners including Tyco were awarded funding from the Assistance to Firefighters Grant program to subject a representative group of floor and roof assemblies to the industry standard fire resistance testing method, (American Society for Testing And Materials) ASTM E119: Fire Tests of Building and Construction Materials. Understanding the testing methods employed and the results of this study, even on a basic level, will assist firefighters in conducting a safer fireground operation the next time the alarm bell sounds. A working knowledge of these results is also a critical step for all members of the fire service who are actively engaged in the growing movement to enhance firefighter safety by modifying the current code requirements for residential construction. Following are some findings from the research:

THE EVIDENCE

- **Residential fires may actually pose risks similar to those in commercial structures**

Many of today’s “typical” house fires are in buildings that based on size and interior volume can and should be categorized as commercial structures with commercial fuel loads. Combined with modern synthetic fuel loads, fires in large, unprotected and un-firestopped voids made of lightweight engineered building materials can be catastrophic. Today’s fireground operations must reflect this new reality.

• **Thermal Imaging Cameras (TICs) don't provide an adequate indication of a weakened floor or pending collapse.** There's a potentially dangerous misconception in the fire service that TICs can detect fire on the floors below or above a firefighter. TICs detect variations in surface temperatures for objects in the camera's field of vision. They cannot detect temperatures in areas that are thermally shielded from the camera's view by the finish materials of a floor or ceiling. During these tests, average temperatures below the assembly were in excess of 1,200 degrees F, while average temperatures on top of the carpet were less than 100 degrees F. The application of water during suppression operations will further mask or eliminate the thermal signatures available to the TIC's sensor.

• **Floor collapse can occur in 6 minutes.** Engineered wood floor assemblies have the potential to collapse very quickly under well-ventilated fire conditions. When it comes to lightweight construction, there's no margin of safety. There's less wood to burn, and therefore less time before the assembly fails. During this research, the shortest failure time was noted during the unfinished/unprotected engineered wooden I-joint test that experienced a total structural collapse at 6 minutes.

• **Tested assemblies significantly weaken well before they completely collapse.** The ASTM E119 definition of collapse requires that the floor totally collapse. Several fire test standards recognized outside the United States, such as ISO 834:1: Fire-resistance tests, Elements of building construction, Part 1, look instead at how long a test sample is able to maintain its ability to support the applied load during the fire test, taking into account when a floor is progressively deflecting or failing prior to a complete structural collapse—clearly a critical piece of information for the fire service.

All lightweight assemblies studied in this series of tests exhibited similar differences in time-to-failure based on the standard applied. Fire service instructors are encouraged to use these different criteria for time-to-failure or collapse to emphasize that test results can only be used for comparison and are not accurate indicators of operational time on the fireground.

• **Plastic ridge vents can mask fire intensity.** In the early stages of the modern roof assembly test, there was a significant amount of smoke emitting from the continuous plastic ridge vent. This is sometimes used by firefighters to gauge the attic fire conditions. As the temperatures increased, the ridge vent melted and collapsed upon itself, sealing the natural opening. The heavy smoke emitting from the continuous ridge vent diminished to a light smoke trail, although the fire was still raging below. Temperatures in the attic space went from approximately 200 degrees F to 1,400 degrees F in less than 60 seconds. These are "flashover" conditions [when all combustible gases in a room reach ignition temperature at the same time] and can cause global failure of structural members including the ceiling. Firefighters conducting size-up and attempting to read smoke conditions from the exterior may be deceived by this change in the volume and velocity of the smoke venting from the roof, and roof teams may conclude that the roof is safe to operate on, when in fact it may be rapidly approaching the point of collapse.

There were a series of tests/demonstrations conducted by Underwriters Laboratories in conjunction with the International Association of Fire Chiefs (IAFC), Michigan State University, and the Chicago (IL) Fire Department (CFD) with grant money awarded through the Department of Homeland Security. A number of tests were conducted using a test furnace and temperature parameters of the ASTM E119 test without 100 percent loading but with loading typical of a residential occupancy. The performance of a protected floor assembly was compared with that of an unprotected floor assembly. All the parameters of these tests were detailed in "Structural Collapse: The Hidden Dangers of Residential Fires," (James M. Dalton of the CFD and Robert G. Backstrom and Steve Kerber of Underwriters Laboratories, *Fire Engineering*, October 2009)

It is important to note the performance of the unprotected lightweight engineered I-joist assemblies compared with other assemblies.



Test results demonstrated that unprotected traditional sawn 2 × 10 lumber construction began to collapse approximately 18 minutes and 30 seconds after ignition. The unprotected engineered lightweight I-joist assembly showed a wide area failure at the 6-minute mark--a marked difference in performance.

Although the results of the Tyco demonstrations and the UL tests seem to be different, if we factor in the time to flashover in the Tyco demonstrations, they are almost identical to the furnace-controlled post-flashover tests at UL.

(Photos courtesy of Underwriters Laboratories)

When these floor assemblies were protected with ½-inch gypsum board, the performance increased dramatically, adding an additional eight to ten minutes of performance. The fire service delegation wanted to return the floor assemblies to the traditional performance levels, so we proposed requiring 5/8 inch gypsum board while recognizing a number of suggestions from earlier efforts, including a trade-off for residential sprinklers systems.

Structural Element – Ceiling Finish	Type of Construction	Ceiling Materials	Floor/Roof Subfloor / Finish	Collapse Time (min:sec)
2 x 10 Joist Floor – Without Ceiling	Legacy	None	1 x 6 and Hardwood	18:45
2 x 10 Joist Floor – With Ceiling	Legacy	Gypsum Board	OSB and Carpet	44:45
2 x 10 Joist Floor – With Ceiling	Legacy	Lath and Plaster	1 x 6 and Hardwood	79:45
12" Wood I-Joist Floor – Without Ceiling	Modern Lightweight	None	OSB and Carpet	6:03
12" Wood I-Joist Floor – With Ceiling	Modern Lightweight	Gypsum Board	OSB and Carpet	26:45
14" Finger Joint Truss Floor – Without Ceiling	Modern Lightweight	None	OSB and Carpet	13:06
14" Finger Joint Truss Floor – With Ceiling	Modern Lightweight	Gypsum Board	OSB and Carpet	26:45
14" Metal Gusset Truss Floor with Cord Splices and Framed Stair Opening – Without Ceiling	Modern Lightweight	None	OSB and Carpet	13:20
14" Metal Gusset Truss Floor – With Ceiling	Modern Lightweight	Gypsum Board	OSB and Carpet	29:15
14" Metal Gusset Truss Floor with Cord Splices, Recessed Lights and Ducts With Ceiling	Modern Lightweight	Gypsum Board	OSB and Carpet	30:08
Metal Gusset Truss Roof – With Ceiling	Modern Lightweight	Gypsum Board	OSB and Shingles	13:06
2 x 6 Joist and Rafter Roof – With Ceiling	Legacy	Gypsum Board	1 x 6 and Shingles	40:00

[Table above shows all the different construction assemblies used in fire tests]

Definitions:

Legacy construction: traditional solid wood beams/joists

Modern Lightweight construction: truss or I-beam assemblies made from wood/metal/synthetic materials

MARKING BUILDINGS

In an effort to promote a fundamental change in firefighter safety and awareness about the presence of lightweight construction a Blue Diamond Program has been developed by Gary Bowker in Winfield, KS after learning about another community on the East Coast that started a similar such program.

The purpose of the Blue Diamond Program is to alert responding firefighters arriving at the scene of a commercial or industrial structure fire where lightweight construction is used by the placement of a blue diamond placard on the exterior of the building. One or more Blue Diamond placards are placed in conspicuous locations on the exterior of the building, thereby alerting responding firefighters immediately upon their arrival.



Blue Diamond signs outside buildings alert firefighters to potential dangers on arrival.

The Blue Diamond is designed with four quadrants, similar to the NFPA 704 Diamond. The all-weather reflective diamond is Safety Blue in color and measures 14 x 14 inches square. The top quadrant contains the letter **T** which denotes the presence of truss construction. The lower left quadrant contains the letter **R** if truss construction is used in the roof system. The quadrant to the right contains the letter **F** if the structure has floor trusses present. If floor trusses are not present, the quadrant is left blank. The bottom quadrant contains the letter **M** or **W** denoting either wood or metal construction.

This information is also contained in the department's quick access pre-fire incident plan.

However, the advantage of the Blue Diamond program is two-fold. First, it provides four key pieces of critical information about the building's construction immediately upon the arrival of firefighters prior to their entry. And secondly, the diamond serves as a constant reminder to firefighters while doing preplanning and familiarization training in the community.

This program was recently presented to the Winfield City Commission and was unanimously recommended for adoption into the Winfield City, KS Fire Code for community-wide use. Other communities using this program include Wilmette, ILL. Green Castle, IN.

These are great examples of the commitment by local community leaders to support the Firefighter Life

Safety Initiatives if we take the time and effort to plan and educate them. But it takes leadership and commitment not only from the fire service, but from local government leaders, too. They must be educated and informed about the hazards and challenges faced by our fire service today. The goal of the Firefighter Life Safety Initiatives Program implemented in 2004 is to reduce firefighter line-of-duty injuries and deaths by 50 percent by 2014.



Blue Diamond signs are also located on the back sides of structures at FD connection.

CONSIDERATIONS

Over the last few decades, millions of single-family homes have been built with truss-constructed roofs that create large, undivided attic spaces and unfinished basements that have unprotected lightweight wood floor systems above them. The above study established that while all unprotected wood floor assemblies are susceptible to early failure when exposed to fire, modern lightweight assemblies fail significantly sooner—and the failures are more global. Unprotected combustible wood construction also poses the threat of accelerated fire development.

CONSTRUCTION

The fire service must support a solution that will permit architects and contractors to continue building structures with engineered lightweight wood truss members. However, the structural integrity of the floor and roof assemblies that come under fire conditions must be improved. Many points of intervention in the construction process could address the problem of the engineered lightweight wood structural member failure under fire conditions. Intervention at any one of these points in the overall process would yield a positive result.

- First, the homebuilders and the construction industry could use a "passive" fire protection approach to enhance the fire resistance of the floor and roof assemblies.
- The manufacturers of engineered lightweight wood structural members could use stronger metal connector plates and gusset plates that penetrate more deeply into the wood.
- Better yet, manufacturers could invest in the research and development of a completely different type of joint connection mechanism that performs significantly better under fire conditions.
- The homebuilders could install additional layers of gypsum board to the bottom of the lightweight wood structural members, which would increase the structural integrity of the floor and roof assemblies for a longer time before structural failure under fire conditions.
- Additionally, local or state legislators could require that all structures, including single-family homes or duplexes, be marked with signs that would indicate the presence of lightweight roof or floor trusses. Such signage on buildings would permit firefighters to change their tactics for fighting fire in buildings with the lightweight truss system.
- However, a higher degree of safety is achieved with an "active" fire protection approach. By fighting the fire in the incipient stage, residential fire sprinkler systems would provide for occupants' life safety and would better protect the entire building, including the roof and floor assemblies, from the intense heat of combustion, prolonging the exposure, which could result in structural failure. In the worst-case scenario, firefighters arriving on the scene would face a much more controlled fire.
- From that perspective, this solution could enhance building occupants and the responding firefighters' safety. The enhancement to civilian safety and the reduction of fire fatalities

make the minimal construction cost increases (1 to 1.5 percent) for the residential fire sprinkler systems much more palatable from a cost-benefit perspective.

SUMMARY

Fires in today's "modern" residential buildings pose greater risks than their "legacy" (traditional solid joist/beams) predecessors. These structures are subject to rapid fire development and spread through areas of unprotected wood and composite construction, leading to earlier collapse and failure of lightweight performance based designed building components.

The fire service needs to react to the changes in building construction methods and the materials used that increase fuel loads and reduce burn time to collapse and or failure when exposed to fire. Firefighters and building occupants are at a greater risk than ever before. It is clear that education alone will not facilitate the need for earlier fire detection for occupant safety or provide firefighters the necessary tools for responding too and attacking fires where firefighters must attempt to make aggressive interior attacks to save lives.

"Risk verses Benefits" need to be addressed as it is important to understand that modern building structures will fail more quickly. Several fire service leaders are already describing modern building construction as "Disposable Housing". Time factors are working against firefighters and occupants, a delayed response will have a direct and adverse impact on the outcome of a fire involving this type of building construction. Firefighters arriving to structures built with engineered light weight building components could face catastrophic structural collapse conditions and must be aware of the potential harm to them. The United State Fire Administration has posted on their web-site research documents that underscore the need for continued efforts to identify the hazards and the response to fires involving modern building construction. The "Time Verses Products of Combustion" illustration demonstrates the correlation between time and magnitude of a fire and the increased hazards firefighters are facing. The illustration also underlines the impact of response time and the importance of sprinklers and early suppression.

The fire service has also learned a couple of other lessons. The first is that it can be successful to work in partnership with nontraditional partners to address safety concerns within the building code arena. The second is the real need to continue to educate the fire service on the importance of full participation within the code-development process and not allow the fire service to have tunnel vision on one issue. Fire service participation can address safety issues at a national level. This importance has been reinforced with the establishment of Strategy 5 of Vision 20/20: The National Fire Loss Prevention Agenda. Strategy 5 identifies the need for fire service participation within codes and standards development.

The information discussed in this White Paper brings to life the severity of the issues related to occupant and firefighter safety when fires occur in modern day performance-based design lightweight construction. The fire service and contributing agencies need to continue discussions on developing lightweight construction hazard identification, occupant safety and provide guidance for establishing situational awareness and developing SOPs (Standard Operating Procedures) or SOGs (Standard Operating Guidelines) and Best Practices for fire departments responding to fires in this type of construction.

These issues cannot be totally addressed by a single fire service agency. If a comprehensive program is to be developed it will require cooperative efforts by a number of fire service entities. Issues of fire safety in lightweight construction will need to involve fire service, building and fire codes, media presentations, insurance input and community and fire service education. Legislation initiatives will also need to be given serious consideration.

BY PROVIDING THE LEADERSHIP ON THIS ISSUE THE FIRE SERVICE CAN INSURE THAT IT REMAINS TRUE TO ITS ROOTS AND HERITAGE OF PROTECTING AND SERVING THE CITIZENS OF OUR GREAT STATE.

For More Information

- For a complete interactive training program that explains the UL study in detail, including the motivation, methodology, testing and lessons learned, go to www.ul.com/fire/structural.html.
- For a chart showing the collapse time for different assemblies, go to <http://tinyurl.com/collapsetimes>.

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In 1988, Vincent Dunn authored *Collapse of Burning Buildings: A Guide to Fire Ground Safety* (Fire Engineering Books and Videos, 1988).

In 2000, Russ Sanders and Ben Klaene addressed concerns about the failures of engineered lightweight wood construction trusses under fire conditions in their book *Structural Firefighting: Strategy and Tactics* (National Fire Protection Association, 2000).

In 2002, James P. Smith addressed the failure of lightweight building components under fire conditions in *Strategic and Tactical Considerations of the Fireground* (Prentice Hall/Pearson Education, Inc., Upper Saddle River, N.J., 2002) 174-190.

In 2008, the National Fire Protection Association published the Fourth Edition of *Building Construction for the Fire Service* by Francis L. Brannigan.

The National Institute of Standards and Technology (NIST) issued the 2007 report “A Study of Metal Truss Plate Connectors When Exposed to Fire.”

“*Lightweight Residential Construction: Collaboration Adds to Firefighter Safety*”- Sean DeCrane, a 19 year fire service veteran, battalion chief for Cleveland Division of Fire. IAAF rep. to International Code Council (ICC).

Recently, Michael L. Smith pointed out the potential danger to firefighters from exposure to trusses under fire conditions in *Building Construction: Method and Materials for the Fire Service* (Pearson/Prentice Hall, Upper Saddle River, N.J., 2008) 134-145.

Also see John Norman, *Fire Officers Handbook of Tactics*, Second Edition (Fire Engineering Books and Videos, 1998) 246-253.

Preventing Deaths and Injuries of Fire Fighters Working Above Fire-Damaged Floors, Workplace Solutions, National Institute for Occupational Safety and Health, February 2009.

“Overcoming Hazards of Lightweight Construction”-, Chief Gary Bowker, recently retired as fire marshal with the City of Winfield, Kansas, He also serves as a Kansas advocate with the National Fallen Firefighters Foundation's Everyone Goes Home program and speaks frequently on firefighter life safety and health issues.

“Lightweight Construction: Is Now the Time to Push for Sweeping Industry Changes?” – Azarang (Ozzie) Mirkhah and David C. Comstock Jr.

Azarang (Ozzie) Mirkhah, P.E., CBO, EFO, CFO, is the fire protection engineer for the Las Vegas (NV) Department of Fire & Rescue. He served on the national NFPA 13 Technical Committee for Sprinkler System Discharge Design Criteria and serves on the IAFC Fire Life Safety Section Board of Directors.

David C. Comstock, Jr, J.D., CFO, CFSI, is a 27-year veteran of the fire service and chief of the Western Reserve Joint Fire District in Poland, Ohio. He is a Chief Fire Officer Designee and lectures and writes on fire service topics relating to chief and company officer operations, liability, and personnel issues. He is also an attorney in the firm of Comstock, Springer & Wilson Co., L.P.A. in Youngstown, Ohio.

Disclaimer:

The Governor's Council on Fire Prevention & Control is made up of 15 organizations that each has an impact on fire prevention and control outcomes in Minnesota. The development of a White Paper by the Council is an attempt to provide an overview on an issue that has been deemed important to fire prevention and control. While generally accepted, it is not intended that every concept in this White Paper is wholly endorsed by all of the member organizations.